

Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

Issued July 12, 1907.

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 298.

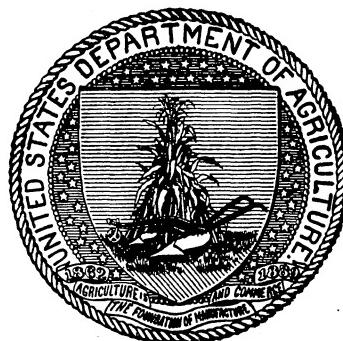
FOOD VALUE OF CORN AND CORN PRODUCTS.

BY

CHARLES D. WOODS, D. Sc.,
Director Maine Agricultural Experiment Station.

Prepared under the supervision of the Office of Experiment Stations.

A. C. TRUE, Director.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1907.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., May 6, 1907.

SIR: Believing that it constitutes a useful summary of data on the subject, I have the honor to transmit herewith and recommend for publication as a Farmers' Bulletin a report on the uses of corn and corn products as food, by Charles D. Woods, director of the Maine Agricultural Experiment Station, who has long been associated with the Office of Experiment Stations in its cooperative nutrition investigations.

Studies of the nutritive value of corn and corn products, particularly those carried on at the Maine and Minnesota experiment stations and at Teachers' College, Columbia University, have formed an important part of the cooperative nutrition investigations of this Office.

The special questions studied have included the digestibility of different sorts of corn bread and other corn-meal dishes, the digestibility of hominy, corn breakfast foods and green corn, the relative nutritive value of corn meal ground in different ways, and the culinary qualities and methods of manipulating old-fashioned and modern corn meal in order to secure uniform results. The data summarized from these investigations, from miscellaneous bulletins and reports of the agricultural experiment stations, and other sources, make it plain that corn meal is one of the most important food cereals when judged by its composition, digestibility, wholesomeness, palatability, and relative economy as a source of nutritive material.

Acknowledgment should be made to Miss Helen W. Atwater for assistance in compiling and arranging the data presented.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

	Page.
Introduction.....	5
Food value of corn.....	8
Structure and composition.....	8
Milling.....	11
Cooking.....	15
Hulled corn.....	21
Corn breakfast foods.....	21
Pop corn and parched corn.....	22
Digestibility of foods made from corn.....	23
Wholesomeness of corn.....	26
Raw corn as an article of diet.....	28
Place of corn in the diet.....	29
Pecuniary economy of corn.....	32
Green corn.....	34
Summary.....	37

ILLUSTRATIONS.

	Page.
Fig. 1. Diagrammatic section of a grain of corn.....	8
2. Cellular structure of a grain of corn.....	9

CORN AND CORN PRODUCTS AS FOOD.

INTRODUCTION.

The tall vigorous cereal plant known as maize, or Indian corn, is a native of the Western Hemisphere, and has been cultivated throughout the warmer regions of the Americas for twenty centuries or more. It has been claimed often that it is also indigenous to the Old World, but there is no warrant for this belief, though it has been grown in parts of Europe in which the climate is particularly favorable ever since Columbus brought the seed from the West Indies. It has also long been grown by the Arabs of northern and the Kafirs of southern Africa, and is a staple crop throughout vast regions of the African continent, as well as of southern and central Asia, China, and Australia. To attain its best development, corn needs both warmth and abundant sunshine, and so the climate of the northern regions of Europe is unsuited to its cultivation and it is there grown mainly for forage, any grain that reaches maturity being inferior in quality and little esteemed for human food.

Following the potato famine of 1847, an effort was made to introduce Indian corn into Ireland, and it has since been considerably eaten there, principally in the form of porridge, or "stirabout;" otherwise it can hardly be ranked as an important foodstuff in Great Britain, except, perhaps, in the dietaries of some of the public institutions, where it replaces more expensive cereals. In the Mediterranean and Balkan regions, however, where conditions are more favorable, its easy cultivation and abundant yield have made it one of the principal food crops. It has been estimated that Indian corn, or Turkish corn, as it is quite commonly known in Italy, forms the main food for two-thirds of the rural population of that country.

Its importance in America may be gathered from its name. Whereas in English-speaking regions of Africa it is known as mealies, and in Europe as maize, a name said to be derived from that originally used in the West Indies, in America it has usurped the name corn, which in Great Britain still refers to any grain regardless of kind. The fact that we sometimes modify this to Indian corn is, of course, a recognition of its origin.

The prevalent opinion is that corn was native to Central America and Mexico, and that it passed through the same stages of cultivation and

dissemination which other important food plants have known. The Maya tribes, the relics of whose civilization are very old, cultivated corn, and it appears as the symbol of religion and prosperity in their art just as do other cereals in the early art of the Eastern Hemisphere. From the Mayas its cultivation spread throughout northern and western South America, the West Indies, and a great part of North America, and traces of corn have been found in the prehistoric mounds of Ohio, in the cliff dwellings of the Southwest, and in Peruvian mummy pits.

The grain kept from decay and destruction by the great dryness of many of these prehistoric burial places differs little, if at all, from varieties grown to-day. The stories often repeated of the raising of plants from such corn, or from the grain found in Egyptian tombs, are without foundation, as the life of the germ is not prolonged indefinitely, even under favorable conditions, though the chemical nature of the grain may remain practically unchanged.

By the time European travelers penetrated into the New World, corn was cultivated by all but the most northern and western tribes of North American Indians. When Cartier ascended the St. Lawrence he found fields of it where Montreal stands to-day. Hariot, in his account of the Virginia Colony, published in 1588, writes of maize as follows: "The graine is about the bignesse of our ordinary English peaze, and not much different in forme and shape, but of divers colours; some white, some red, some yellow, and some blew. All of them yeelde a very white sweete flowre; being used according to his kind, it maketh a very goode bread."

The early chronicles of Virginia contain many descriptions of the cultivation of corn, beans, pumpkins, and other plants by the Indians; and in very early times in the Jamestown colony Indian prisoners were forced to teach the English settlers how to plant and till this grain. An early chronicle of the Plymouth settlement told how, in the dreadful winter of 1620-21, the colonists bought "eight hogsheads of corne and beanies" from their Indian neighbors, and in the following spring learned from a friendly red man "bothe ye manner how to set it and after how to dress and tend it." For a time it was the principal breadstuff in the American colonies. Little by little, however, as wheat and other cereals became acclimatized these supplanted it among the well to do, though it has never passed entirely out of use in any section of the United States, and in some districts, particularly in the South and Southwest, it is still a staple cereal grain.

According to the census of 1900, almost a third of all the land under cultivation in the United States was devoted to corn. It was grown on 88.6 per cent of all the farms in the country, and the crop for 1889 was valued at \$828,258,326. Wheat, the next most important crop,

occupied only 18.1 per cent of the cultivated land, and was valued at \$369,573,528. Of course these figures do not represent the relative importance of the two grains as human food, for while practically all the wheat is used in that way, either at home or in those countries to which it is exported, the greater part of the corn crop is used for feeding stock or as raw material in several important manufacturing industries. A better idea of its importance as human food may be gained from a recent compilation of American dietary studies made with many families in different parts of the country. Among 72 families in comfortable circumstances corn preparations furnished on an average 1.6 per cent of the total food; among 161 families, mostly foreigners, in the congested districts of large cities, only 0.3 per cent; among Tennessee and Georgia mountaineers, 23 per cent, and among southern negroes 32.5 per cent. These figures refer only to the meals, flours, and similar preparations made from the ripe dried grains.

While meal, hominy, and similar products are the principal corn foods, there are a number of others of much importance. The unripe ears, especially of certain sweet varieties, are a favorite vegetable on American tables, and pop corn is a typical American food product of which the total amount consumed is very large. The roasted kernels of ordinary corn are sometimes used as a substitute for coffee, and apparently form a part of some of the mixtures commonly sold as coffee substitutes. Starch, glucose, gluten, and oil are also made from corn; and these and other important corn products will be discussed in later sections.

From an agricultural standpoint, corn is of the utmost importance, and this might be known, if for no other reason, from the fact that there is, perhaps, not one of the agricultural experiment stations, established in every State and Territory, which has not studied some phase of the corn question, either methods of cultivation, improvement of varieties, composition, feeding value for farm animals, or importance as a food for man. The State departments of agriculture and like organizations have also carried on much work of a similar nature. The importance of corn as an article of diet has been taken up especially at the Maine and the Minnesota experiment stations. The Department of Agriculture, and particularly the Bureau of Chemistry,^a have also been large and important contributors to our knowledge of the composition and uses of corn and corn products.

As regards the preparation of corn for the table the literature is very considerable, almost every cookbook and journal of cookery containing recipes for corn dishes, while several such books are devoted exclusively to corn and corn products.

^a U. S. Dept. Agr., Bureau of Chemistry Bul. 13, pt. 9, and Bul. 50; The food value of maize, etc., in Report on the Use of Maize (Indian corn) in Europe (U. S. Dept. Agr., Spec. Rpt. 1891).

FOOD VALUE OF CORN.

The food value of corn and its products, as compared with each other and with other food materials, of course depends mainly on the amount of nutritive materials or nutrients which the digestive organs can extract for the use of the body. Besides the water found in all food materials, even those which are apparently perfectly dry, the actual nutrients are grouped in four classes: (1) Protein or nitrogenous material; (2) fat; (3) carbohydrates, including starches, sugars, and the very indigestible constituents known as crude fiber or cellulose; and (4) mineral matters or ash. The two functions of the food are to furnish material for the building up and repair of body tissue and to supply energy for muscular work and body heat. Protein, fats, and carbohydrates alike can yield energy, but since only protein can serve for the necessary tissue building, this is usually considered its main function and the fats and carbohydrates are relied on to furnish most of the energy. All the changes which corn or other food undergoes in being prepared for eating are intended mainly to add to its palatability and get it into a form in which the nutrients can be most easily and completely utilized by the body.

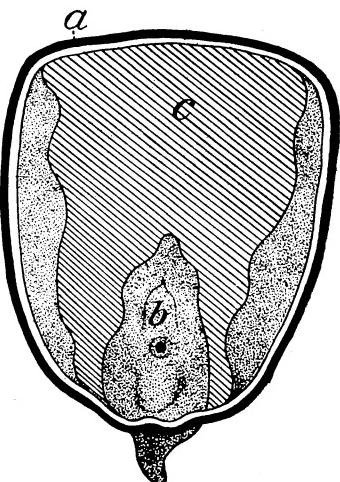
STRUCTURE AND COMPOSITION.

Although the stalk and leaves are important cattle feeds, only the kernels of corn are ordinarily used for human food. They grow in

double rows along a woody cob, from which they are easily shelled when ripe. The color of the skin may be white, yellow, red, purplish blue, or a combination of these, according to variety. They are all either white or yellow inside and differ little on an average save in color. The kernel or seed, it must be remembered, is not inert, but a living thing, which under favorable conditions will develop into a new plant, and each part of it is made up of cells especially fitted for a particular rôle in this process of reproduction. Roughly speaking, the seed consists of three main divisions: The skin, the germ, and the endosperm (see fig. 1). The skin, which makes about 6 per cent of the weight of the seed, holds the whole

FIG. 1.—Diagrammatic section of a grain of corn: *a*, skin; *b*, germ; *c*, endo-sperm.

together and protects the delicate interior parts. It is made up principally of tough cellulose or crude fiber with some mineral matters



embedded in it. The germ is larger in corn than in most cereals, and forms in average corn about 10 per cent by weight of the grain, whereas in wheat it is only 6 or 7 per cent. It contains the embryo from which the new plant will develop under favorable conditions. The endosperm constitutes about 84 per cent by weight of the grain, and represents the food which the parent plant has stored for the early growth of the new plant. In the germ and endosperm, the cellulose walls of the cells are very much thinner than in the skin, and surround a network of nitrogenous material called protoplasm in which the life of each cell seems to reside. The food materials which the plant has stored for future use lie in the meshes of this protoplasmic network, together with some moisture; in the germ much of the stored material is fat and mineral matters. In the outer layers of the endosperm (see fig. 2), there are stored grains of a protein substance known as aleurone, and in the inner portions are found quantities of tiny starch grains with small amounts of protein and mineral matter. Table 1, taken from analyses made at the New Jersey Agricultural Experiment Station, shows how these constituents are distributed throughout the grain, the data being expressed on a water-free basis.

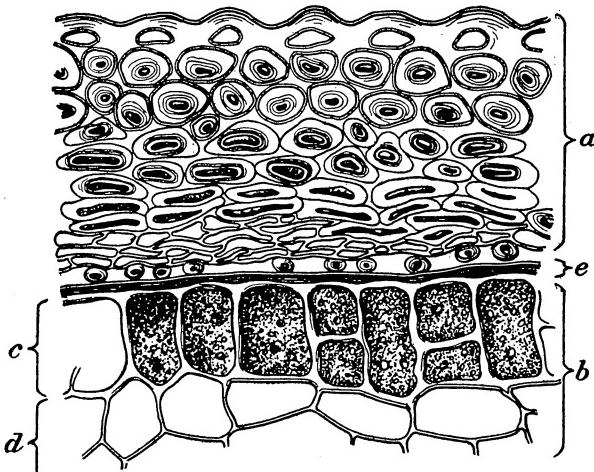


FIG. 2.—Cellular structure of a grain of corn: *a*, skin; *b*, endosperm consisting of (*c*) aleurone cells and (*d*) starch cells; *e*, membrane.

TABLE 1.—Composition of different portions of a grain of corn.

Portion of corn kernel.	Proportion in original grain.	Water.	In water-free material.				
			Protein.	Fat.	Total carbohydrates.		Mineral matters.
					Starch, sugar, etc.	Crude fiber.	
Whole kernel.....	100.0	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Skin	5.6	24.7	12.7	4.3	79.3	2.0	1.7
Germ	10.2	29.6	21.7	29.6	74.1	16.4	1.3
Endosperm	84.2	24.7	12.2	1.5	44.7	2.9	1.1
					85.0	.6	.7

From these figures it may be calculated that 51 per cent of the cellulose of the grain is found in the skin, 65 per cent of the fat and about 16 per cent of the protein in the germ, 90 per cent of the starch and 84 per cent of the protein in the endosperm.

Grain of any kind is hygroscopic—i. e., has the power of absorbing water from the air—and the amount of moisture in it varies according to the climate and other conditions under which it is grown and stored. The proportion of nutrients in different varieties of the same species also differs considerably, being influenced by the selection of seed, the method of cultivation, the season, and other factors. The figures in the following table were prepared from many analyses and represent the average composition of the whole grains of corn and other common American cereals as ordinarily found in the market.

TABLE 2.—*Average composition of cereal grains.*

Kind of cereal.	Water.	Protein.	Fat.	Total carbohydrates.		Mineral matters.	Fuel value per pound.
				Starch, sugar, etc.	Crude fiber.		
Indian corn.....	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Calories.
Barley.....	10.8	10.0	4.3	71.7	1.7	1.5	1,800
Buckwheat.....	10.9	11.0	2.3	69.5	3.8	2.5	1,735
Kafir corn.....	12.6	10.0	2.2	64.5	8.7	2.0	1,600
Oats.....	12.5	10.9	2.9	70.5	1.9	1.3	1,630
Rice.....	11.0	11.8	5.0	59.7	9.5	3.0	1,720
Rye.....	12.0	8.0	2.0	76.0	1.0	1.0	1,720
Wheat.....	10.5	12.2	1.5	71.8	2.1	1.9	1,740
	10.6	12.2	1.7	71.3	2.4	1.8	1,750

As far as these figures show, the average water content of these cereals is almost the same, ranging from 10 to 12 per cent. Corn on an average contains 10 per cent protein, which is about 2 per cent less than the average rye or wheat contains, but 2 per cent more than the average rice. Its fat amounts to 4.3 per cent, or about the same proportion as is found in oats and over twice as much as in most of the other grains. In the proportion of starch they contain, corn, wheat, and rye are practically the same, and surpass all the other common grains except rice. The cellulose content of corn is smaller than that of any of the other cereals except rice, and it also contains a comparatively small proportion of mineral matters.

Though the proportions of the several nutrients in corn and other common cereals are much the same, the individual compounds^a making up these groups differ considerably. As shown by extended studies at the Connecticut State Station, zein is the typical proteid

^a For discussion of the properties of corn proteids, see Connecticut State Sta. Rpts. 1891, p. 136; 1896, p. 391. Data regarding fat are summarized in Ann. Rpt. Ohio Dairy and Food Comr., 21 (1906), p. 18, and of carbohydrates in U. S. Dept. Agr. Bureau of Chemistry Bul. 13, pt. 9.

of maize, and it differs in its properties considerably from the gluten of wheat or the proteids of other cereal grains. The fat of corn has a different chemical composition from that of wheat or other grains, and the ash also is characteristic.

There is known to be some variation in the number and kind of starches, sugars, cellulose, and other bodies included under the heading "Carbohydrates," which occur in corn and other cereals, but it is generally believed that the bodies like starch which occur in the different plants have the same percentage composition. In size, appearance, the distribution of the concentric layers making up the granule, the readiness with which the starch absorbs water and is acted upon by ferment, and in other properties, starch grains occurring in different cereals exhibit considerable variations. The starch granules of corn resemble those of oats somewhat in appearance, but are larger.

Fat, when burned in the body, gives off 2.25 times as much heat as carbohydrates and protein, and corn, which contains relatively large proportions of both fat and carbohydrates, has a comparatively high fuel or energy value. The points in which the chemical composition of corn is superior to the other common cereals, then, are its richness in fat and starch and its small content of crude fiber. Its deficiencies lie in the small quantities of protein and mineral matters. The quality of its protein is less desirable for bread making than that of wheat and rye, as will be discussed later (see p. 17).

MILLING.

Occasionally whole grains of corn are used for human food, as in parched corn, pop corn, etc., but as a rule it is found preferable to break them up more or less before cooking. The Indians ground corn between two flat stones or pounded it, sometimes parching it beforehand. Another simple method, employed by the pioneer settlers, was to grate the newly ripened ears on a coarse grater, and many persons still maintain that in this way the best flavor of the grain is obtained.

Before the development of railways and elaborate milling machinery each community had its mill, usually by a stream, and here all the grain of the neighborhood was ground. The corn was simply crushed between the grooved millstones to the desired fineness. If the meal was intended for human food, the coarse particles of skin or bran were usually bolted out, though this was often done at home instead of at the mill. Nowadays cereals of all sorts are shipped from many districts to central mills in which complicated machinery grinds the grain much more carefully than was possible fifty years ago, and although the milling of corn is not as elaborate as that of wheat, it is no longer a simple process of crushing. To begin with, the grain is

usually kiln dried (see p. 28), a process which hinders decay by lessening the vitality of molds and decay-producing bacteria, if they are present, and by driving off the water, without which such minute forms of life can not grow. Drying the grain also makes the skin separate more readily from the grain, and its removal before grinding is an advantage, since the skin consists largely of indigestible cellulose, which renders the meal coarse and rough without adding much to the food value. The germ lowers the keeping quality of the meal because its abundant fat easily becomes rancid, and now it is usually removed before the grain is ground. A machine known as the "degerminator" loosens both skin and germ, which are then easily bolted out, and the remaining endosperm is ground alone and bolted and purified by means of air currents. The offal removed consists of the hull, germ, floury particles, and some of the flinty portion of the corn, and constitutes 30 to 35 per cent of the entire weight of the grain. Meal from such degenerated grain is commonly called "granulated corn meal" and has almost replaced the old-fashioned kind for human food in the North, although the latter is still very popular in the Southern States. Both kinds are made in varying degrees of fineness. Very finely ground and bolted corn meal is known as corn flour, and is made from both yellow and white corn.

While meal is the form in which corn is best used for bread making, the less finely ground products, such as hominy and samp, are often preferred for porridge. The use of these terms is very uncertain and confusing. In colonial days in New England, samp designated the kernels of freshly harvested corn, but this use has now disappeared. In some parts of the country, the kernels which have been simply crushed sufficiently to loosen the hulls are known as samp, and those which have been crushed into bits not much larger than mustard seeds are called hominy, but in other sections the names are exactly reversed, while in many regions all such corn preparations are called hominy. The germ and skin are now usually removed in preparing these products, and their chemical composition is not, therefore, the same as that of the original grain. How this varies may be seen from Table 3, which gives analyses of corn prepared in different ways. The corn meals, both bolted and unbolted, were simply crushed, while the granular meals, hominy and samp, were "degerminated" before grinding.

TABLE 3.—*Average composition of corn products and wheat flour.*

Kind of material.	Water.	Protein.	Fat.	Carbohydrates.		Mineral matters.	Fuel value per pound.
				Starch, sugar, etc.	Crude fiber.		
Corn, whole grain, average.....	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Calories.
Corn, whole grain, average.....	10.8	10.0	4.3	71.7	1.7	1.5	1,695
Corn with low protein content.....	10.5	6.0	3.8	78.5	—	1.2	1,685
Corn with high protein content.....	10.5	12.9	4.4	70.8	—	1.4	1,695
Corn, white.....	11.4	10.8	5.0	68.8	2.5	1.5	1,690
Corn, yellow.....	11.9	10.7	4.8	68.9	2.2	1.5	1,690
Sweet corn (matured).....	8.8	11.6	8.1	66.8	2.8	1.9	1,750
Pop corn.....	10.7	11.2	5.2	69.6	1.8	1.5	1,710
Hominy, fine.....	11.0	9.4	.7	78.2	.4	.3	1,810
Samp, coarse.....	10.8	8.3	.5	79.4	.7	.3	1,770
Corn meal (wholegrain ground), unbolted.....	12.0	8.7	4.7	71.1	2.2	1.3	1,850
Corn meal (wholegrain ground), bolted.....	12.0	8.9	4.9	72.0	1.2	1.0	1,765
Corn meal, granulated.....	12.5	9.2	1.9	74.4	1.0	1.0	1,770
Corn flour, i. e., finely ground and bolted corn.....	12.6	7.1	1.3	77.5	.9	.6	1,645
Corn starch.....	—	—	—	90.0	—	—	1,675
Liquid glucose (for table use).....	16.0	—	—	83.5	—	.5	1,120
Corn oil.....	—	—	100.0	—	—	—	4,040
Wheat flour.....	11.1	11.4	1.3	75.5	.1	.6	1,770

The values given in the table for corn of low and of high protein content show that there may be a considerable range in the proportions of the different nutrients present. Such variations are due to cultural varieties, to methods of cultivation, seed selection, and other similar factors, and are noted in corn of all types. The influence of different factors on the protein content has been studied at the Illinois, Minnesota, Kansas, and other agricultural experiment stations with the object of breeding varieties of corn which are especially rich in nitrogenous constituents, and this work has been attended with considerable success.

As the average figures show there is no appreciable difference in the composition of white and yellow corn, the variations which have been noted being smaller than are found in different analyses of either sort. When samples of the same grain are compared, whole corn and the unbolted meal made from it have the same composition, as the process of grinding neither takes from nor adds to the nutritive material present. The small variations between the whole corn and unbolted meal shown in the table are due to the fact that the figures are the average of many analyses of different samples. When the corn meal is bolted, about one-eighth of the original grain is removed, this material consisting chiefly of the cellulose of the skin. The removal of this material of course increases the proportion of the other materials present, and in this way it may be seen that the bolted corn meal is richer than the unbolted in nutrients other than crude fiber. Hominy, samp, and granulated corn meals resemble each other in composition, such differences as those indicated in the table being no greater than

might be expected in a number of individual samples of either food material. In the manufacture of these corn products, the skin and germ have been removed and with them most of the crude fiber and considerable of the fat and mineral matter of the original grain. It might seem that in thus removing the fat and ash the food value would be decreased. This is only true in a measure, for it must be remembered that the proportion of carbohydrates, which are valuable nutrients and have the same functions as fat in nutrition, is increased. If a person lived exclusively on corn meal, the loss of the mineral matters might be serious, for a certain amount is necessary for the proper nourishment of the body. However, there is every reason to believe that the ordinary mixed diet contains a sufficient amount of the different ash constituents.

From the manufacturer's standpoint the removal of the germ does not represent a loss, as it is used for the manufacture of gluten feeds—so important for live stock—and corn oil, which has many industrial uses and is utilized to some extent as a salad oil and as a culinary fat. Cooking tests made in the home economics department of the Ohio State University showed that products in which corn oil was used as part of the shortening were of excellent quality, flavor, and appearance. Culinary fats are on the market which are claimed to be corn products, and studies carried on at the Connecticut State Experiment Station show that they contain corn oil as their characteristic constituent, the oil being stiffened with a harder fat.

The fine corn flour sometimes seen in American markets is granulated corn meal ground to the finest powder. What is called corn flour in England is known in the United States as cornstarch, and is the practically pure starch separated from the endosperm by special processes. It is commonly used for thickening puddings, sauces, etc., and in other ways, and has practically replaced arrowroot and the fine-grained tropical starches in invalid cookery.

The liquid glucose known as confectioners' glucose, or sometimes as mixing glucose, is a thick colorless liquid when well made, and is prepared in large quantities by inverting cornstarch, usually by boiling it with dilute hydrochloric acid and refining and evaporating the product. The liquid glucose sold for table purposes is often flavored with caramel or other materials and frequently contains added cane sugar.

Starch sugar or solid glucose is made in much the same way as the liquid product except that the treatment with acid is continued until practically all the starch is inverted. Although the liquid glucose and the starch sugar are not as sweet as cane sirup and cane sugar, they are considered to be perfectly wholesome, when well made, and of definite food value.

These glucose products made from corn are much used in the manufacture of certain forms of confectionery, being better adapted for certain kinds than cane sugar as they do not so readily harden and crystallize. The manufacture and use of liquid glucose and starch sugar have been spoken of in earlier publications of the Department.^a

As is shown by the figures in Table 3, wheat flour of average composition is richer in protein than old-fashioned corn meal and contains about the same proportion of starch and less fat, crude fiber, and ash. In composition granulated corn meal differs from wheat flour mainly in containing less protein and more starch. Generally speaking, it will be seen that corn products compare favorably as regards nutritive value with such a standard food product as wheat flour.

COOKING.

Cooking cereals improves them in many ways. If bacteria or molds have found their way accidentally into the raw grain they are destroyed or rendered harmless by the action of heat. Although they knew nothing of micro-organisms, the American Indians and many other primitive people usually parched their grain before storing it, and in this way sterilized it as satisfactorily for their purposes as do modern millers by kiln drying. Cooking develops palatable flavors in foods. In the case of cereals and other foods rich in carbohydrates, the flavors are doubtless due in large part to the browning or caramelization of these constituents. Cooking also changes the mechanical condition of grain foods so that they may be more conveniently eaten and more readily acted upon by the digestive juices.

Parching is one of the simplest methods of cooking grains, and also doubtless the method first adopted by primitive man. Simple parched corn, it is said, is still eaten in central Asia and is regarded as a very convenient form of food for travelers in that part of the world.

Some of the desirable changes which heat produces in grain are most satisfactorily brought about when water is present, and from time immemorial it has been customary to mix grain with water or milk when preparing it for human food. The indigestible fiber of the cell walls breaks down under the combined action of moisture and heat, and so the real nutritive materials of the grain are more accessible to the action of the digestive juices than would otherwise be the case, for mastication, even if long continued, does not break down the cell walls of raw grain as easily or completely as is the case after cooking. Under the action of the moist heat the starch grains expand or swell and become soft and more porous, while a greater or smaller proportion of the starch may undergo what is known to the chemists as hydrolysis

^aU. S. Dept. Agr. Yearbook, 1905, p. 241; Farmers' Bul. 93.

and be transformed from a substance insoluble in water to others which are readily dissolved. When there is no water present, as in parching, or when the water is very largely removed, as in baking or roasting, the starch tends to turn brown in color and acquires a pleasant toasted taste. In this process dextrin is formed, and as a whole these changes are akin to those noted in the caramelization of sugar.

Little is known regarding the changes which take place in the protein and fat during the cooking of corn, but they are doubtless much the same as with other foods, protein being coagulated by heat and fat broken down to some extent into simpler bodies if the heat is intense or long continued. The amount of water which corn meal and other corn products require in cooking varies considerably, the fine meal, for instance, absorbing less water than the coarse.

The proportion of water in a cooked dish is obviously determined by the amount of liquid originally present or added in preparation and the amount evaporated by the heat of cooking. Catherine A. Williams^a studied the amount of water absorbed by a number of cereal foods and found that 100 grams of hominy sprinkled into boiling water, cooked until soft, and then drained, weighed 623 grams, or in other words had absorbed 523 grams of water. The original material contained 13 per cent water and the cooked 87 per cent. When 100 grams of a cornstarch preparation was cooked with water 618 grams of thick porridge or blanc-mange was obtained with a water content of 87 per cent as compared with 13 per cent in the original material used.

Corn meal is cooked in a great variety of ways, but most of the dishes fall under two general heads, namely, bread prepared by baking, and porridge or puddings made by boiling. In the case of the ready-to-eat corn breakfast foods the cooking has been done at the factory; the preparation at the factory usually consists in rolling or flaking and sometimes parching and flavoring the thoroughly steamed or boiled and softened grain.

The composition of corn breads and corn porridge and other cooked corn products is shown in Table 4 in comparison with uncooked corn meal and wheat bread. The flavor, food value, and other characteristics of the corn foods are taken up in the sections which follow the table.

^aJour. Amer. Chem. Soc., 29 (1907), p. 574.

TABLE 4.—*Composition of cooked corn preparations, corn meal, and wheat bread.*

Kind of material.	Water.	Protein.	Fat.	Carbohydrates.		Mineral matters.	Fuel value per pound.
				Starch, sugar, etc.	Crude fiber.		
Hominy, boiled.....	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Calories.
59.3	2.2	0.2	17.8	0.5	380		
Hoecake.....	52.8	4.0	.6	40.0	0.2	2.4	885
Johnnycake.....	29.4	7.8	2.2	57.5	.2	2.9	1,385
Boston brown bread.....	43.9	6.3	2.1	45.7	.1	1.9	1,110
Corn breakfast foods, flaked, (partially cooked at factory).....	10.3	9.6	1.1	77.9	.4	.7	1,680
Corn breakfast foods, flaked and parched (ready to eat).....	7.3	10.1	1.8	77.2	1.2	2.4	1,725
Indian pudding.....	60.7	5.5	4.8	27.5	1.5		815
Cornstarch blanc-mange (made with cornstarch and water).....	87.3	2.9	.1	9.5	.....	.2	230
Parched corn.....	5.2	11.5	8.4	72.3	2.6		1,915
Popped corn.....	4.3	10.7	5.0	77.3	1.4	1.3	1,880
Hulled corn.....	74.1	2.3	.9	22.2	.5		490
Granulated corn meal.....	12.5	9.2	1.9	74.4	1.0	1.0	1,655
Wheat bread.....	35.3	9.2	1.3	52.6	.5	1.1	1,205

As has been stated, granulated corn meal and ordinary wheat flour are not very different in chemical composition, and the corn is often cheaper in price; nevertheless, wheat ranks far ahead of corn as a breadstuff, perhaps the most important reason for this being that wheat yields a lighter and more porous loaf with yeast or other leavening agent. This is due to the character of its protein, which consists largely of a substance known as gluten, so elastic in its nature that it stretches the dough into little pockets as the gases from the yeast expand within it. The heat of cooking hardens the gluten and so the finished loaf retains its porous structure. The only cereal which compares with wheat in the elastic and tenacious qualities of its nitrogenous constituents is rye. Corn contains no such gluten, and even when mixed with equal amounts of rye or wheat flour and raised with yeast, as in the old-fashioned "rye and Indian" bread, it does not give anything like as porous a loaf as either wheat or rye alone.

For the most part, therefore, corn breads are of the unleavened or flat bread type and are granular rather than porous. They are usually baked in thin loaves or cakes, and so the lack of gluten is less important. They do not keep as fresh as yeast-raised breads and should be eaten soon after baking. The simplest kind of corn bread is that in which the meal is mixed with water or milk and baked. Such were the cakes which the American Indians baked in the ashes of their camp fires or on a heated stone; such are the tortillas of Spanish America and the hoecakes of our Southern States (which get their name from the fact that the cake is sometimes baked on the blade of a hoe held over the coals), and the ash cakes or corndodgers, which, wrapped in a cabbage leaf, are baked in the hot ashes of the fireplace. Johnnycake and corn bread, popular in New England and other parts of the country, used to be prepared in much the same way,

and were baked on a board before the fire and in later times in the oven; but nowadays they are usually made with part corn meal and part wheat flour and slightly raised by the addition of baking powder, eggs, etc. Other corn breads and cakes are made by mixing eggs, sugar, sour milk and baking soda, butter, lard, or other materials with the meal. Sometimes white and sometimes yellow meal is used in these preparations, each sort having its advocates who maintain that it is much superior to the other. As a matter of fact, analysis has shown that there is no constant difference in the composition of the two sorts of meal, and it seems equally certain that there is no uniform difference in flavor or cooking quality.

The famous Boston brown bread was originally a mixture of rye and Indian meal sweetened with molasses and lightened a little by the gases evolved by mixing sour milk and soda. It was made into large, thick loaves, which required long, slow cooking, such as was best obtained in the old-fashioned brick ovens. The weight of the loaves was fixed by law in Massachusetts in colonial times, and bakers were required to stamp their initials on the bread. Nowadays Boston brown bread is usually made with corn meal, rye, and whole-wheat flour, and is cooked by steam in small loaves in tightly covered tins. Combined with beans it has long been the orthodox Saturday-night supper or Sunday breakfast in many parts of New England. Such brown bread canned in small tins is a common commercial product. It is probably made like any other "Boston brown bread" except that it is cooked and sterilized in the sealed cans.

A sweet cake something like gingerbread is sometimes made by mixing molasses and spice into a johnnycake batter, and is an old-fashioned favorite in many homes. Projaca is a Servian corn bread in which eggs and cheese are mixed with maize meal, the dough covered with leaves and baked either in pans or in the ashes, something like the ash cakes of our Southern States.

In Italy a considerable effort has been made to substitute maize wholly or in part for the more expensive wheat in making macaroni and other similar pastes. These foods, it should be remembered, which are used in the United States as an occasional substitute for vegetables and in similar ways, in Italy are eaten in large quantities as a staple food by all classes and often form the main if not the whole of a poor man's meal. Their advantage over flour, aside from their compactness, is that they are less liable to become moldy or to be attacked by insect enemies and may be easily and quickly prepared for the table with only the simplest cooking conveniences. While wheat is much better adapted to making these pastes, owing to its tenacious gluten, such goods made of mixtures of wheat and maize or of maize alone are by no means unpalatable. Their use,

however, is certainly not common, and their manufacture, which attracted considerable attention in Italy not long ago, seems never to have assumed much commercial importance.

Practical cooks differ in opinion regarding the relative values of the old-fashioned bolted and the new granulated corn meals in bread making. There is certainly a difference in flavor, due to the removal of the germ in grinding the granulated meals, but whether the distinctive flavor thus acquired is an improvement or not is largely a matter of individual opinion, and undoubtedly a person usually likes the sort to which he has been accustomed.

As to the texture of bread, the difficulty experienced with the newer types of meals often arises from the fact that recipes intended for the old-fashioned sorts are used without modification. Because they contain less fat the granulated meals require more shortening material than those which include the germ. They also absorb water less readily than the old-fashioned sorts, and for this reason some cooks prefer to scald the granulated meal before mixing it with the other ingredients. An extended series of tests carried on at Teachers' College, New York, as a part of the nutrition investigations of the Office of Experiment Stations, has shown that, when properly manipulated, bread from granulated corn meal is fully as light as that made from plain bolted meal, and that under such conditions the difference in texture and quality of the breads and other products from the two types of meal are not particularly marked.

The early colonial records tell us that the Indians pounded corn, often previously parched, to a coarse meal and made a sort of mush from it. Sometimes nuts, berries, beans, pumpkins, etc., formed part of the dish, while sometimes meat or fish were used much as the Scotch mix meat with oatmeal in their meat brose. It is not surprising that the colonists took kindly to corn-meal porridge, as it was similar to the dishes made from other cereals which they had known at home.

"Hasty pudding," or corn-meal mush, which may be made with either milk or water, is a dish which can be quickly cooked, as its name implies, though long slow cooking is generally conceded to yield a better dish. Good cooks always insist that the water must be vigorously boiling and that the meal must be slowly stirred in, a little at a time, in order that the mush may be smooth and of the proper consistency. Hominy and samp, which are much coarser than meal, require longer cooking, and for this reason are often considered less convenient than other similar cereals. The very coarse hominy is not an economical dish where cooking is done on a gas stove and fire must be kept especially for it, but in households where

the range is hot all day a dish of it in a double boiler at the back of the stove will almost cook itself. Sufficient water is important in cooking hominy and samp, as the grain, if not constantly covered with water, becomes rather hard and dry. On the other hand, too much water makes the dish gummy and unattractive. To be properly cooked each grain of hominy, though soft, should retain its distinct form, as is the case with well-cooked rice. Old-fashioned meal and hominy made from corn which includes the germ have a more distinctive flavor than the products made from degerminated grain, and for this reason they are often preferred for porridge making, though the use of one sort or the other is, of course, entirely a matter of taste. A New England cookbook of one hundred years ago gives the following advice: "For Sunday morning in winter fry the hasty pudding that was left over from Saturday night's supper. Eat it with West India molasses or Muscovado sugar." Fried mush and fried hominy are still favorite breakfast dishes. They are also sometimes served with meat in the place of vegetables, as is also plain boiled hominy.

Corn-meal mush is so much used under the name of polenta in many parts of Italy that it may almost be called the national dish. Polenta is made much like hasty pudding, except that some grated cheese or lard or other fat is commonly one of its ingredients. With poorer people polenta often constitutes the bulk of the daily fare, while in more well-to-do families it is an accompaniment of meat dishes and other foods, and is served in a variety of ways, many of them worthy of a trial by American housekeepers.

Tamales, a Mexican corn-meal dish formerly little known to American cooks except in the southwestern United States, are now comparatively common. In making these, corn meal suitably prepared is mixed with meat or chicken and chili peppers or other seasoning, wrapped in corn husks and boiled until well cooked. So well known has this dish become that canned tamales are on the market.

Indian pudding, a favorite family dessert in this country, is made by mixing molasses, butter, spices, etc., with corn meal into a batter with milk or water. It used frequently to be boiled in a cloth like Christmas plum pudding, but now is more commonly baked or steamed in a deep dish.

Many cooks use corn starch for thickening sauces, etc., because it gives them a smoother consistency than flour. It also forms the basis of puddings, in which it is mixed with milk, sugar, eggs, etc. Such dishes are very nutritious and palatable, and are believed to be easily digested, which accounts for their use in invalid cookery.

Corn-meal gruel, a palatable dish once much more commonly prepared for invalids than at the present day, is cooked for such a long

time and with such large proportions of water that the crude fiber of the corn meal is quite completely broken down and the starch very largely converted into a smooth, almost jelly-like condition.

Though the proportion of water may be higher in mush or porridge than in corn bread, yet such foods are nutritious and may be readily combined with other dishes to form a palatable and wholesome diet.

HULLED CORN.

Hulled corn, or lye hominy, is prepared by steeping the kernels in hot water which contains lye, or sometimes simply a small bag of wood ashes, until the hulls are loosened or softened. The corn is then soaked in plain water until the lye is washed out and then boiled until it is soft. When it is eaten in milk as a breakfast dish or used in other ways, its distinctive flavor makes it a food much liked in many families. One hundred years ago it was a common custom for housewives to prepare hulled corn for the use of their families, but the process is time-consuming, and it is now commonly purchased from dealers, who often make a specialty of supplying it. Lye hominy is a common product in Washington and Baltimore markets, and the hulled corn vender is well known in many New England towns and elsewhere in the northern United States. A number of brands of canned hulled corn are on the market which differ in no appreciable degree from the freshly prepared product. As the figures in Table 4 show, hulled corn has much the same composition as boiled hominy. It owes its distinctive flavor in considerable measure to the treatment with lye.

CORN BREAKFAST FOODS.

There is at the present time a great number of proprietary breakfast foods on the market, some of which are ready to eat, while others need only a little cooking, and so are easier to prepare for the table than the old-fashioned meals or grits made from similar grains. A number of these breakfast foods are made from corn. In the case of the partially cooked and ready to eat brands the processes of manufacture are apparently the same as with similar foods made from other grains. Selected grain, carefully freed from all impurities, is steamed or cooked until it is soft, then flaked or rolled by passing it through heavy rollers, and dried. Sometimes the flakes are parched with or without the addition of malt. Variations in the process of manufacture give the granular preparations and other varieties with which we are all familiar. Corn breakfast foods, like other goods of this type, are very commonly marketed in packages. The food value of these corn preparations and other breakfast foods has been discussed in an

earlier bulletin of this series.^a In general it may be said they are comparatively concentrated foods, as they contain little water, and are quite similar to corn meal in chemical composition.

POP CORN AND PARCHED CORN.

Special varieties of corn with hard, small kernels are used for popping. Pop corn was formerly sold on the ear, but now it can be bought already shelled, in bulk, or packed in small cardboard boxes. Such corn has been carefully kiln-dried and perhaps pops more evenly than the home-dried product. In the popping, which takes place when the kernels are exposed to intense heat like that from a good bed of coals, the endosperm expands and pops or bursts white and crisp through the torn skin. It was formerly supposed that this bursting was due to the sudden expansion of the fat in the grain, but it is now known that it is caused by the sudden expansion of the cell moisture into steam. In pop corn the cell walls are very firm and hard and do not burst until the pressure is quite considerable. Ordinary varieties of corn, in which the cell walls are softer, when treated in the same way, expand and sometimes burst more or less, but do not have the characteristic popped appearance.

During popping, corn loses considerable water, and so it contains a larger proportion of nutrients than the original grain. Chemical changes take place also in the nutrients themselves, though they are not very well understood. Part of the carbohydrates are undoubtedly browned or caramelized, and it is believed that the peculiar flavor of popped corn is due in a measure at least to this fact. It is a matter of common experience that the flavor and texture of popped corn deteriorates if it is kept for any considerable time after popping. Apparently the loss of crispness is due to the fact that the freshly popped corn is so very dry and porous that it readily absorbs moisture from the air.

Popped corn is usually eaten out of hand and can hardly be called an important food product, though the total amount used in the United States is large—about 300 carloads annually, it has been estimated. Puddings and other foods are sometimes made from popped corn, and popped corn and milk is an old-fashioned dish which is wholesome and may be made to accord with modern habits by using it as a breakfast cereal. Popped corn is, however, most commonly eaten with salt and butter or made into a sort of confectionery with molasses or sugar.

Popped corn resembles other corn products in composition, except that it contains less moisture. Its very porous structure makes it a comparatively bulky food. So far as can be learned, its digestibility

^a U. S. Dept. Agr., Farmers' Bul. 249.

has not been studied experimentally, but there is no reason to suppose that it is not easily and thoroughly digested.

It is often stated that pop corn is used in large quantities in the manufacture of breakfast foods and for the adulteration of flour, but both these statements are denied on good authority.

Parched corn, made from ordinary varieties which expand but do not burst on heating, is eaten to a limited extent out of hand. As the figures in Table 4 indicate, it does not differ very materially in composition from popped corn.

Infusions of parched corn or of "browned" corn meal or parched brown bread crusts are old-fashioned coffee substitutes which many persons consider among the most palatable cereal coffees. The food value of "corn coffee," like that of all similar beverages, depends very largely upon the sugar and cream added to it, for the small quantity of caramel or other browned material which it contains in solution is not of much importance, and 99 per cent of the infusion is water.^a

DIGESTIBILITY OF FOODS MADE FROM CORN.

The real value of any food material depends not only on the amount of nutrients which it supplies but also on the proportion of these nutrients which the digestive organs can convert into such a form that they may be absorbed into the blood and made available for the nourishment of the body—in a word, upon digestibility. The thoroughness of digestion of the more common food products has been carefully determined. A number of digestion experiments have been made with corn, the first of these being perhaps that reported by Rubner about thirty years ago. He found that a man on a diet of corn-meal porridge, with a little butter, meat extract, and cheese, retained in the body 85 per cent of the protein, 83 per cent of the fat, 97 per cent of the carbohydrates, and 70 per cent of the ash which the food supplied. Somewhat later Malfatti, an Italian, studied the digestibility of maize porridge (polenta) eaten with cheese and found that 93 per cent of the protein, 91 per cent of the fat, 98 per cent of the carbohydrates, and 81 per cent of the ash were digested. Somewhat lower values were found when the polenta was eaten without the cheese. In more recent Italian experiments with polenta, much the same results were obtained, though the values found for protein were rather lower. Macaroni and similar pastes made wholly or in part of corn meal, though somewhat more digestible than the corn-meal mush were found to be a little less digestible than similar foods made from wheat.

Harcourt^b at the Ontario Agricultural College and Experimental Farm studied the digestibility of a number of breakfast foods, includ-

^a See also U. S. Dept. Agr., Farmers' Bul. 249, p. 33.

^b Jour. Soc. Chem. Indus., 26 (1907), p. 240.

ing corn-meal mush. According to his experiments, 74 per cent of the protein and 99 per cent of the carbohydrates of corn-meal mush are digested when it forms a part of a simple mixed diet.

The digestibility of corn-meal mush or "hasty pudding" and boiled hominy has also been studied recently at the Maine Experiment Station. The hasty pudding was made by stirring meal into salted water and cooking it in a double boiler. It was found that in the case of a mixed diet containing considerable quantities of hasty pudding 89 per cent of the total protein and 99 per cent of the carbohydrates were digested, while 97 per cent of the energy of the diet was available for the body. When the hasty pudding was eaten with a little milk or sugar and constituted a considerably larger proportion of the diet, 82 per cent of the protein and 99 per cent of the carbohydrates were digested and the quantity of energy available was the same as before. The calculated values for the digestibility of hasty pudding alone were: Protein 73 per cent, carbohydrates 98 per cent, and available energy 93 per cent. The experiments of similar nature which were made gave for hominy as a part of a mixed diet, for hominy with milk and sugar, and for hominy alone practically the same values as were obtained for the mush. From all the experimental data the conclusion may be fairly drawn that the nutritive ingredients of dishes made by cooking corn in water are well assimilated.

The digestibility of corn breakfast foods has been studied at a number of the experiment stations, particularly in connection with the cooperative nutrition investigations of the Office of Experiment Stations. As has been pointed out in an earlier bulletin of this series,^a which discusses the digestibility and nutritive value of cereal breakfast foods as a whole, 74 per cent of the protein, 90 per cent of the fat, and 99 per cent of the carbohydrates of corn breakfast foods are assimilated, while 95 per cent of the energy is available. These values, it will be seen, are very similar to those given above for corn-meal mush, etc.

An extended series of experiments on the digestibility of corn bread of different sorts, including hoecake, johnnycake, and Boston brown bread, was also carried on at the Maine Experiment Station. In every case the same sort of granulated corn meal was used. The brown bread was made of equal parts of corn meal and wheat flour mixed with milk, molasses, baking powder, and a little salt. It was steamed in cans for four hours. The johnnycake was made of equal parts of corn meal and wheat flour, with suitable quantities of milk, sugar, baking powder, and salt. Neither flour nor baking powder was used in the preparation of hoecake. The meal was stirred into boiling water until a thick pudding was formed, which was immediately spread in thin sheets upon hot well-greased iron plates and

^a U. S. Dept. Agr., Farmers' Bul. 249.

baked at once. For purposes of comparison, digestion experiments were also made with wheat-flour bread. The foods under consideration were eaten with milk and sugar, or sirup in the case of hoecake—this ration being termed a simple diet—and as a part of a more elaborate mixed ration which also included canned peaches and meat.

The average figures which were obtained for the different corn-bread rations with the healthy young men who served as subjects and the calculated values for the bread alone are shown in Table 5, which also contains, for purposes of comparison, the results of the similar study with wheat bread made from standard patent flour.

TABLE 5.—*Average digestibility of corn bread of different sorts compared with wheat bread.*

Kind of food.	Entire ration.			Corn products alone.		
	Protein.	Carbohydrates.	Heat of combustion of digested material.	Protein.	Carbohydrates.	Heat of combustion of digested material.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Hoecake in mixed diet.....	90.0	98.8	92.6	-----	-----	-----
Hoecake in simple diet.....	87.0	98.7	93.7	77.1	98.6	93.8
Hoecake with sirup.....	84.4	99.2	95.5	78.8	98.7	94.0
Johnnycake in mixed diet.....	90.1	99.3	93.9	-----	-----	-----
Johnnycake in simple diet.....	89.6	98.7	93.8	86.3	98.9	93.5
Boston brown bread in mixed diet.....	89.5	99.4	92.9	-----	-----	-----
Boston brown bread in simple diet.....	87.4	98.7	93.5	83.0	98.6	93.4
Wheat bread in mixed diet.....	92.6	99.0	98.2	-----	-----	-----
Wheat bread in simple diet.....	89.2	98.9	94.0	85.6	98.9	94.0

The data in the table show the digestibility of the nutrients of the total diet, including the given corn product, and that of the nutrients of the corn product itself when thus eaten. The results as a whole are very favorable indeed. In all the experiments with corn bread the carbohydrates of the corn were almost completely utilized by the body. The figures for protein vary somewhat with the different products, indicating that the method of preparation may have some influence upon the thoroughness of digestion. It was least thoroughly digested in hominy and hasty pudding (see p. 24). The figures for protein of hoecake, and hoecake with sirup, are a trifle larger. On the whole the experiments indicate that the protein of corn is slightly less thoroughly digested than that of wheat, but the difference is too slight to be of much practical consequence. As a matter of fact, in the case of johnnycake and brown bread, which are practically breads made of corn meal alone or mixed with wheat or rye flour, the protein was as thoroughly digested as that of yeast-raised bread from white wheat flour, with which experiments were made for comparison.

By comparing the percentages of digestibility of corn alone with those found for the total simple diets and mixed diets it will be seen that its protein is in every case less thoroughly digested than that of

the total diets and that the protein of the total simple diets is less thoroughly digested than that of the mixed diets. These facts are in accord with observations in many similar experiments, and are believed to indicate that the digestibility of protein depends somewhat upon the proportion of protein to other nutrients in the diet. The Italian experiments in which the protein of cheese—a material rich in protein—and corn porridge were more thoroughly digested than that of corn porridge alone or with butter, strengthen this belief.

All the above-mentioned tests referred to thoroughness of digestion, and give no information with respect to the ease or comfort with which food is assimilated. The time which elapses between the eating of food and the excretion of the undigested residue of it does not vary much with the ordinary foods, and the rapidity of digestion therefore usually has reference to the length of time which food remains in the stomach. Although to a healthy person this is probably a matter of little moment, it may be a question of considerable importance with invalids. Unfortunately it is very difficult to obtain definite information on such matters. Beaumont, in his famous observations on the Canadian trapper with a gunshot wound in his stomach, found that corn bread remained in the stomach three hours and fifteen minutes and ordinary wheat bread three hours and thirty minutes. In this connection, however, it must be remembered that starch, the main ingredient of cereal food, is digested in the intestines rather than in the stomach and that the way in which such observations as Beaumont's should be interpreted is a matter on which there are differences of opinion. Common experience, however, it may be fairly claimed, has shown that well cooked corn products are usually digested without distress or disturbance.

WHOLESAFENESS OF CORN.

There are all sorts of popular notions about the effect of corn on the body. Thus, one occasionally hears it said that it is indigestible and unfit for persons of weak digestion. Old-fashioned corn meals in which the skin was imperfectly bolted out and the fat of the germ, which readily becomes rancid, was retained, may have been digested somewhat less easily or less thoroughly than some other cereal foods, but it does not seem probable that the finely granulated corn meals now commonly found on the market which contain little save the starch and protein of the grain would tax the digestive organs very severely. Experiments have certainly shown that such corn meal is very well assimilated. Foods containing coarse material like the bran of cereals are believed to stimulate the movement of food through the intestines and so to counteract any tendency to constipation. From this standpoint the use of the coarser meals has an advantage which

in most cases will doubtless make up for any differences in ease or thoroughness of digestion.

The digestibility of any ordinary cereal food is increased by thorough cooking, as this tends to break down the crude fiber of the cell walls and changes the physical or chemical nature of the starch so that it is more readily acted upon by the digestive juices. The more cellulose a food contains the more important it is that the cooking should be thoroughly done, and so the desirability of properly cooking corn meal is obvious.

Corn is frequently spoken of as a good winter food, but as too "heating" or "heating to the blood" for summer. Just what these expressions mean is not easy to say. Carefully conducted experiments have shown that as a rule the consumption and digestion of carbohydrates and fats does not materially increase the output of the body heat, but that protein does cause an increase in the amount radiated or otherwise given off by the body. Generally speaking, however, in the few experiments which have been made with man this increased liberation of heat has not been accompanied by a sensation of warmth. Corn is not a typical proteid food, as its protein content is not over 10 per cent, so it would hardly cause an appreciable increase in the output of heat from the body as compared with wheat or other common foods also supplying the different classes of nutrients in reasonable proportion.

Corn is rich in fat and carbohydrates and so is a fattening food, as its extended use in the feeding of farm animals abundantly demonstrates. Fat is known to protect the body from extremes of temperature and so it may be that corn has been spoken of as a heating food, particularly valuable in the winter diet, on account of its fat-producing qualities rather than because of any specific heat-producing properties.

The term "heating foods" seems often to mean simply hearty foods; that is, those which because of their bulk, the length of time they remain in the stomach, or for other reasons delay the normal recurrence of hunger for a longer time than usual. Some corn dishes, like corn-meal cakes with sirup, or the crackling bread of southern cooks which contains the pork cracklings or scraps left after lard is rendered, are unquestionably hearty foods, but no more so than similar dishes made from other cereals. Certainly simple corn breads and other simple corn dishes do not seem to particularly merit this designation.

In this connection it is interesting to note that corn has always been a more important foodstuff in the southern United States, Mexico, and the Mediterranean regions than in corresponding northern regions, even where it is a common market commodity, and this would certainly indicate that there can be no reason for supposing

that cold weather is more appropriate for the use of corn foods than warm. The most reasonable deduction from available data is that the way in which corn dishes are prepared and cooked, and the foods with which they are combined are more important factors than climate in regulating the use of these foods, and that, rightly used, corn bread and other corn dishes are wholesome at all seasons.

A curious and often fatal disease, which has at times been very prevalent in Italy and the Balkans, was formerly believed to be due to the large quantities of maize eaten by the poor of these regions. This disease, which in Italy is called pellagra, begins with eruptions on the skin and in later stages is attended by serious intestinal and cerebral disturbances, and often terminates fatally. Carefully conducted investigations have shown that this disease is not due to the maize itself, but to a mold or fungus which readily grows in the grain when it is stored in damp places, as is commonly the case in these regions, and which in its growth develops poisonous substances. Fortunately, this fungus has never infected corn in the United States, but the evils which attend such infection emphasize the need of taking adequate measures to prevent it and show the advantages of thoroughly sterilizing the grain, as by kiln-drying, before it is used by either man or animals, for when once started such an infection is very difficult to check.

The occasional digestive disturbances which are noted after eating corn and corn products are of the same sort as occur with other foods, and may be due to overindulgence, to some personal idiosyncrasy, or some similar cause, and may be left out of account in considering the general question of the wholesomeness of this grain. That it is wholesome and well suited to its numerous uses as a food product is abundantly proved by its long-continued use under a great variety of circumstances and conditions and the high opinion in which it has always been held. Scientific investigations have abundantly justified the popular conclusions on the subject.

RAW CORN AS AN ARTICLE OF DIET.

Any extended study of questions concerned with the selection and use of foods shows that such topics have received much attention since earliest times, and that many widely divergent and contradictory theories have been proposed. One of the theories which has again attracted attention is that cooking decreases the value of food. Regarding corn and other cereals, the upholders of this theory say that not only is the healthy body able to digest them raw but also that the heat of cooking greatly decreases their nutritive value by destroying the "vital principle" of the grain. Exactly what this "vital principle" is or what effect it has on the body is not explained.

Indeed, aside from the possible value in some cases of the ferments present in the raw food, there is no experimental evidence to support the theory nor does physiological chemistry give any ground for believing it. Persons of healthy digestion can undoubtedly eat raw cereals in reasonable amounts with impunity, provided the materials are thoroughly masticated and are free from accidental contamination from dangerous micro-organisms, which often accompany dust and dirt and are conveyors of disease. Raw starch is digested in the body, but it is much more difficult to break down the cell walls protecting the starch in raw grains than it is when they have been cooked.

In cases of constipation the quantity of crude fiber and the coarse, mechanical condition of this raw corn and other similar cereal products may sometimes have a beneficial effect, but judged by composition and digestibility they can certainly possess no advantage over the cooked foods. To forego the advantages produced by cooking seems to involve a useless waste of digestive energy for persons of delicate digestion, if not for all.

PLACE OF CORN IN THE DIET.

According to commonly accepted dietary standards, the daily food of a man doing light to moderate muscular work should provide about 0.23 pound of protein for the building and repair of his body tissues and other uses and 3,000 calories of energy for his bodily activities. Of course, as muscular work increases or decreases, these quantities, particularly the energy, should be correspondingly increased or decreased. Women on an average are smaller in stature than men and so require relatively less food, as do also children. The ideal diet is one which supplies the right quantities of nutrients in the proper proportion and in an appetizing and attractive form, while at the same time it is reasonable in cost.

About 3 pounds of corn meal would furnish the protein called for by the above-mentioned standard, but would supply with it about 4,830 calories of energy or more than one and one-half times as much as is required. If, on the other hand, the amount should be so reduced that only the desired energy is supplied, the protein furnished would be only about two-thirds of the assumed requirements. Thus, it is evident that corn contains too little protein in proportion to its energy-yielding constituents to be a well-balanced food when used alone. Even if it furnished the proper proportions of protein and energy, corn would hardly be an ideal food for use as the sole article of diet, for it would be very bulky, 3 pounds of corn meal, when cooked into bread or mush, representing a rather formidable amount of food. Moreover, corn, or, indeed, any other single food, would not long seem appetizing to a person accustomed to a varied diet, and it is an accepted physiological fact that appetizing qualities have much

to do with stimulating the activity of the digestive organs. The fact that, under stress of need, people have lived for considerable periods on corn alone does not prove that such a diet is to be recommended, but rather that the body has great powers of adapting itself to an emergency. In the United States it has always been the custom to combine corn with other foods rich in protein, as such combinations as mush and milk, Boston brown bread and baked beans, and hominy and fried chicken testify, and these combinations are more rational than either food used alone. The Italians often mix cheese with corn in making polenta or mush, and thus increase the protein content, as well as vary the flavor of the dish. Milk, which contains considerable protein, is also commonly used with corn meal by the peasants of southern Italy; and, indeed, it may be said to be a general rule with corn as with other carbohydrate foods that the attempt is universally made to provide by proper food combinations the protein which the body seems to demand.

Among the negroes and mountain whites of the southeastern United States large quantities of corn are used in combination with salt pork, sirup or molasses, milk, some wheat flour, and more or less green vegetables and fruit. The common designation "hog and hominy" points out the leading features of this diet and suggests its faults. Salt pork, which consists almost wholly of fat, adds very materially to the energy value of the diet without adding much of any protein, and none of the other foods supply enough of this constituent to make the diet well balanced. Among 70 families in the mountain regions of eastern Tennessee the average diet yielded 0.18 pound of protein and 3,600 calories of energy per man per day, which is 77 per cent of the protein and one-fifth more than the energy suggested by the dietary standard referred to above (see p. 29). In this diet, which was cooked and served in the simplest ways, corn supplied about 35 per cent of the protein and 30 per cent of the energy. Similar conditions were noted in the families of negroes in Alabama, and also studied in connection with the nutrition investigations of the Office of Experiment Stations. Taken as a whole, the people who live very largely on such a diet do not seem to be in as robust physical condition, as well nourished, or as productive of efficient labor as others who are more fortunately situated. How much of this can be attributed to a lack of protein and too great a proportion of fats and carbohydrates and how much to poor cooking, monotonous fare, and generally unhygienic living conditions it would be hard to say. From the results of the Alabama studies, however, made at and near Tuskegee, and from general sources of information, it seems certain that better health and more efficient work attend improved conditions of living and diet. When the corn was more generously supplemented by milk, eggs, meat, cowpeas, and other

legumes, and the foods were better prepared, a general improvement was noted in the Alabama families, as, indeed, it generally is when a better and more generous diet is made possible for a family or community long accustomed to opposite conditions.

With a mixed diet of meat, eggs, milk, vegetables, fruit, etc., such as is found in homes in the United States, the exact proportion of protein to energy in each individual food material is of less consequence than when the food consists of two or three materials only. If breakfast with its bread and cereal yields too little protein this will ordinarily be offset by dinner in which meat, custard, cheese, beans, lentils, or similar foods will probably be used. In such a diet as this, corn ordinarily is used in place of some other cereal which it approximates in composition, and the diet as a whole is usually well balanced.

One good feature about corn meal is that it can be made into an appetizing bread perhaps rather more easily and quickly than wheat flour. During the civil war large quantities were used by the soldiers of both armies and it was found that, although the meal did not keep as well as wheat flour, a palatable corn cake could be made from it under almost any conditions, whereas it required some considerable experience and skill to make even fairly edible wheat bread with the simple utensils which were oftentimes the only ones available. For the same reason campers and others who live for any length of time away from a base of supplies not infrequently prefer corn meal to wheat flour, especially when it has been thoroughly kiln-dried (see p. 12). It has been said that the name johnnycake is a corruption of journey cake, and that corn bread was so called because it could be so easily prepared on the road. In the ordinary household with its well-equipped pantry and kitchen this feature is not a matter of as much importance as it would be under other conditions, but even here corn bread may often help the housekeeper in an emergency more easily than could wheat biscuits.

Corn meal, when used for bread, cakes, porridge, puddings, etc., and hominy and other corn foods are cheap and apparently well-digested sources of both protein and energy, and although like other cereal foods, not well fitted to supply a suitable diet if used alone, these corn dishes combine readily with other materials to form a ration which is in accord with accepted dietary standards, and which is at the same time palatable and wholesome. The corn dishes which may be easily prepared are very numerous, and this important food-stuff might well be used more frequently than is at present the case in the average American home, to give an inexpensive variety to the diet as well as for its generally valuable qualities.

PECUNIARY ECONOMY OF CORN.

The relative economy of different food materials depends not merely on the price per pound but also on the amount of digestible nutrients which a given sum will purchase. Ten cents spent for potatoes will yield a much larger bulk of food, for instance, than the same sum spent for flour, but so great a proportion of potatoes is water, or juice, and inedible skin that the body actually obtains less than half as much protein and energy as from 10 cents' worth of wheat flour.

Table 6 compares corn and a number of other foods as sources of digestible protein and energy when valued at certain assumed average prices per pound.

TABLE 6.—*Cost of nutrients of corn and of other food materials at certain assumed prices.*

Kind of material.	Price per pound.	Cost of 1 pound of protein.	Cost of 1,000 calories of energy.	Amount for 10 cents.				
				Total food material.	Protein.	Fat	Carbohydrates	Energy.
Corn meal, granulated...	2.5	0.32	.02	4.00	.31	.07	2.96	6,540
Do.....	3.0	.44	.02	3.33	.23	.06	2.48	5,534
Hominy.....	4.0	.62	.02	2.50	.16	.01	1.97	4,178
Samp.....	5.0	.78	.03	2.00	.13	.01	1.57	3,342
Corn breakfast food, flaked and parched.....	13.0	1.73	.08	.77	.06	.01	.60	1,335
Wheat flour.....	3.0	.31	.02	3.33	.32	.03	2.45	5,440
Wheat breakfast food.....	7.5	.73	.04	1.33	.13	.02	.98	2,235
Wheat bread.....	5.0	.64	.04	2.00	.16	.02	1.04	2,400
Oatmeal.....	4.0	.29	.02	2.50	.34	.16	1.66	4,500
Beans, white, dried.....	5.0	.29	.03	2.00	.35	.03	1.16	3,040
Corn, green, canned.....	10.0	4.21	.23	1.00	.02	.04	.18	430
Potatoes, 60 cents per bushel.....	1.0	.67	.03	10.00	.15	.01	1.40	2,950
Beef, sirloin.....	20.0	1.28	.20	.50	.08	.06	.....	515
Beef, shoulder clod.....	9.0	.57	.13	1.11	.18	.10	.....	795
Pork, roast, lean.....	12.0	.92	.10	.83	.11	.19	.....	1,035
Pork, salt, fat.....	12.0	6.67	.03	.83	.02	.08	.....	2,950
Butter.....	25.0	25.00	.07	.40	.....	.32	.....	1,365
Cheese.....	16.0	.64	.08	.63	.16	.20	.02	1,185
Milk, 7 cents per quart.....	3.5	1.09	.11	2.85	.09	.11	.14	885

The first column of figures in the table shows the assumed price per pound, the second and third compare the foods at these assumed prices as sources of protein and energy, while the remaining columns show the amounts of nutrients and energy which 10 cents expended for the foods at the stated prices per pound would furnish.

Of the foods included, corn meal, oatmeal, and wheat flour, it will be seen, are the cheapest sources of protein with the exception of dried beans, and also of energy with the exception of potatoes and salt pork. Corn meal sells at a lower price than hominy or samp; and, as they all have practically the same composition and so furnish nearly the same amounts of protein and energy per pound, it is obvious that the meal is more economical than these products. The specially prepared corn breakfast foods included in the table are more than

twice as expensive sources of protein and energy as hominy or samp, and still more expensive as compared with corn meal.

From this table it would appear that the low-priced wheat flour is in reality fully as cheap as corn meal, and this is undoubtedly true when these foods are brought under ordinary market conditions in most parts of the country. In remote sections, however, such as the mountain districts of our southeastern States, where climate and other conditions are favorable to the production of corn, where milling facilities are primitive and communication with other regions difficult, it requires a smaller outlay for a man to furnish his family with corn than with wheat. In the dietary studies made among the southern mountaineers already referred to, 20 per cent of the total food was in the form of corn and the total cost of the food per man per day ranged from 3 cents to 16 cents, the average being 9 cents. In 20 studies made in an especially remote district of eastern Tennessee the average cost was only 7 cents, and with these families corn was also the staple food. Whatever one may think regarding the ultimate physiological and sociological value of such a diet, there can be no two opinions regarding its immediate cheapness.

Throughout Europe more intensive cultivation is required than in the United States, and wheat commands relatively a much higher price than corn where the latter is a market commodity. There is also a difference on the side of wheat in the United States, but it is less than it was formerly, for during the last fifty years the price of corn has risen while that of wheat has decreased. Pereira and Lee,^a writing as early as 1850, reported that a bushel, or about 60 pounds, of good corn could be bought for about 56 cents, and that a pound of this would yield from 2.5 to 3 pounds of food, so that "if an individual could live on this alone his annual expense for food would be \$3.65, or say \$15 for a family of five." According to the dietary standards previously referred to it would require nearly 3 pounds of corn to furnish the necessary protein; but even so, a man in 1850, if it had been possible for him to subsist on corn alone, would have expended but 3 cents a day, or \$10.95 a year, and at present average prices for corn such a diet would cost about the same. These calculations are interesting as illustrations of the relation between the cost and nutritive value of an important foodstuff, but, of course, do not imply that it would be possible or desirable for a person to live on corn or any other single foodstuff.

Food materials of nearly all kinds are more expensive in Europe than in the United States, and the diet of many persons, particularly those of limited means, are very much less generous or varied there than here. Rye bread and milk or cheese with some vegetables

^a Treatise on Food and Diet. New York, 1850, p. 161.

constitute the bulk of the food throughout large regions of northern Europe. Corn meal from the United States could be sold in these regions even more cheaply than the rye or other cereals so extensively used at present, and both the United States and the European governments have tried to introduce corn as a substitute for, or a supplement to, other cereals; but in spite of its cheapness the people have not taken to it any too kindly, in part, doubtless, because the home-grown corn with which they are familiar is of inferior quality, and in part because they are ignorant of the proper ways of preparing and cooking it and do not understand how to make from the corn dishes which are similar to those which they prepare from other grains. Such difficulties, however, should not be insurmountable, for the use of corn has become widespread in China and other parts of the East, and the differences in dietary habits which were overcome before this was possible must have been greater than those which exist between the Europeans in question and ourselves. It would be of mutual advantage to American producers and European consumers if such difficulties could be set aside, and it seems probable that eventually this will be accomplished.

GREEN CORN.

Green corn or sweet corn is commonly spoken of as a distinctively American dish, but this is not really the case, although the cultivation of certain varieties for use as green vegetables is much more common here than elsewhere. Green corn is little known in the northern and western parts of Europe, though it may be found, for instance, in the large London markets, and canned corn is obtainable in many European cities. In the Balkan regions, however, the unripe ears are roasted and considered a delicacy as with us. In his report for 1901 the commissary-general of the United States Army states that the American troops sent to the relief of Peking obtained green corn from the natives along the line of march and notes that the Chinese frequently cooked it on the cob, though they regard it more as a fruit than as a vegetable. In Africa and Australia, where corn is extensively grown, the unripe ears are used as food, though not as generally as in the United States and Canada. A recent publication^a notes the extended use of both green and ripe corn by African natives who cultivate corn and a number of other food plants. The article further states that they are accustomed to chew the green succulent corn stalks, which are sweet, as they do sugar cane.

As everyone knows, the special varieties of corn which are characterized by a sweet taste are most prized for use as a vegetable, and analysis shows that these varieties actually contain considerably

^a Jour. Trop. Med. London, 10 (1907), p. 157.

more sugar than corn raised for other purposes. Taking the average of a number of analyses, 5 per cent sugar and 15 per cent dextrose and other soluble carbohydrates have been reported in ripe sweet corn as compared with 3 per cent sugar and 3 per cent dextrose and other soluble carbohydrates in the varieties of corn commonly raised for feeding purposes and for manufacture into meal. The Massachusetts experiment station has reported 0.8 per cent cane sugar and 0.4 per cent glucose, making 1.2 per cent total sugar as the average amounts present in a large number of samples of sweet corn gathered when just ready for the table. Much higher values than these have been noted in individual samples.

Corn on the cob is not very convenient to serve or eat and this method of cooking it would doubtless have been abandoned long ago if cutting the kernels from the cob before cooking did not materially modify the flavor. In household practice it is usually more convenient to boil the ears, but in old-fashioned fireplaces or at camp fires roasting is a deservedly popular method of cooking corn. Green corn, like other vegetables, is at its best when freshly gathered. It is commonly believed that corn which has been picked any considerable time is not as sweet as that which is freshly gathered. That this is actually the case was proven by recent investigations by the Bureau of Chemistry of this Department, which showed that sugar disappears from the kernels very rapidly after the ear is separated from the stalk, and within 24 hours after harvesting, if exposed to ordinary temperature, is almost entirely absent. The season of corn is more nearly limited to the season of maturity in a given region than that of almost any other common vegetable, for it can not be stored for any considerable time in good condition, even with modern appliances, and corn grown in warm climates and shipped long distances to our winter markets is very expensive and rather uncertain as to its quality. Corn, however, may be readily canned on a commercial scale, and when this is properly done it retains many of its desirable qualities. It is not surprising, therefore, to find that canned corn is one of the most popular canned vegetables. In canning corn the process is much the same as that followed with other vegetables. The kernels cut from the cob and salted are sterilized in sealed cans, the aim being to apply the heat in such a way and for such a time that the micro-organisms causing decay will be destroyed, while at the same time the process is so regulated that the flavor and appearance are changed as little as possible. For a long time the attempts which were made to can corn on the cob were not very successful, but methods have been improved, and corn canned on the cob is becoming an important article of commerce.

Succotash, a mixture of unripe corn and beans cooked together, is a dish which was borrowed, name and all, from the Indians, and has

been a favorite since colonial times. To vary their winter diet, the colonists often cooked dry ripe corn and beans together, but such a dish does not possess the palatability of that made from green corn. Corn with tomatoes is another mixture which many persons like and which is quite commonly served. Canned corn with tomatoes is on sale, but is much less common than canned succotash or canned corn alone. Small immature ears of unripe corn are sometimes used in mixed pickles, particularly in Europe, and relishes are also made in the United States from green corn, both as a domestic article and commercially. The amount of green corn used for such purposes, however, is very small compared with that used fresh or canned.

Table 7, which follows, shows the composition of green corn, fresh and canned, succotash, and corn and tomatoes, and also includes for purposes of comparison similar data for some other common vegetables.

TABLE 7.—*Average composition of green corn and other vegetables.*

Kind of material.	Refuse.	Water.	Protein.	Fat.	Total carbohydrates.		Ash.	Fuel value per pound.
					Starch, sugar, etc.	Crude fiber.		
Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories.	
Green corn on cob, as purchased.....	61.0	29.4	1.2	0.4	7.7	0.3	180	
Green corn on cob, edible portion.....		75.4	3.1	1.1	19.2	0.5	.7	470
Green corn, canned.....		76.1	2.8	1.2	18.2	.8	.9	455
Green corn and tomatoes, canned.....		87.6	1.6	.4	9.1	.5	.8	225
Succotash, canned.....		75.9	3.6	1.0	17.7	.9	.9	455
Beans, Lima, fresh, as purchased.....	55.0	30.8	3.2	.3	9.1	.8	.8	255
Beans, Lima, fresh, edible portion.....		68.5	7.1	.7	20.3	1.7	1.7	570
Potatoes, as purchased.....	20.0	62.6	1.8	.1	14.7	.8	.8	310
Potatoes, edible portion.....		78.3	2.2	.1	18.0	.4	1.0	385
Tomatoes, fresh.....		94.3	.9	.4	3.3	.6	.5	105

Young corn contains on an average a little more protein and starch and a little less sugar and cellulose than the mature grain, but differs chiefly from the dry ripe corn in containing much larger percentages of water. It furnishes about as much food material, pound for pound, as potatoes, but its nutritive value, as with all fresh vegetables, is low compared with that of such foods as dry ripe beans or the cereal grains. When purchased on the ear it includes over 60 per cent inedible portion or refuse, whereas the amount lost with the skin of potatoes is usually only 20 per cent. Considering the comparatively high price of green corn of good quality in the markets of large towns and cities, it is certainly a more expensive food than potatoes or some other vegetables. If grown in the home garden, however, such comparisons do not hold, and under any usual circumstances it is a reasonably economical vegetable when in season. Like most green vegetables it is more valued for its palatability and for the pleasant variety which it gives to the diet than for the nutri-

ents which it supplies, and is certainly not expensive as compared with other foods of this class.

It is often stated that green corn is very indigestible. If the ears are not fresh and of good quality the corn may cause digestive disturbances, particularly if improperly cooked; and, as is the case with almost any other food, overindulgence may be followed by unpleasant consequences. When eaten from the cob green corn is often not thoroughly masticated and the kernels or the skin which covers them often pass through the body apparently unchanged. While of course this lessens the amount of nutritive material which the body obtains from the corn, there is no reason to suppose that this is harmful for a healthy person; but if desired the condition may be very largely avoided by running a knife lengthwise along the rows and splitting the skins of the kernels before they are eaten.

A digestion experiment made at Wesleyan University, Middletown, Conn., by Bryant and Milner, in connection with the nutrition investigations of the Office of Experiment Stations, showed that green corn when eaten in considerable quantity as a part of a simple mixed diet was fairly well assimilated, about 84 per cent of the protein and 97 per cent of the carbohydrates which it supplied being retained by the body, and on the whole it compared favorably with other vegetables which were studied at the same time. Such data are too limited for general deductions, but taken in connection with the almost universal experience that green corn when well cooked is a wholesome vegetable, they indicate that it does not deserve the reputation for "indigestibility" sometimes ascribed to it.

Succotash and corn and tomatoes are similar in composition to the vegetables of which they are composed, while canned corn has practically the same composition as the freshly cooked product.

Green corn, both fresh and canned, is often used for making soups, fritters, and other dishes, and in this way adds to the palatability and variety of the diet.

SUMMARY.

Although a native of the new world and first extensively cultivated there, Indian corn or maize is now grown very generally wherever the climate permits. In the United States corn is by far the most important cereal, and is grown in every State, though the south-eastern and middle western sections are the great corn regions. The greater part of the corn crop is used for feeding live stock and poultry, or for starch making or other manufacturing purposes. Nevertheless, corn has always been and still is a favorite and very important source of human food in America, and especially in the South Atlantic States, where it ranks with wheat as a breadstuff.

The germ of corn makes up an unusually large percentage of the kernel as compared with most grains, and as the germ is very rich in fat the grain as a whole is characterized by an unusually large proportion of this constituent. The proportion of protein is also fairly high. Carbohydrates, particularly starch, make up the greater part of the nutritive material of corn, as of other cereals. Until about fifty years ago corn was simply ground and then bolted or sifted at the mill or at home in making meal for cookery, but now it is usually kiln-dried and deprived of the outer skin and germ before grinding. The modern granulated corn meal is bolted to free it from offal products and is finer and keeps better than the old-fashioned sort, though it does not differ from it very materially in composition except that it contains a little less fat and crude fiber. The removal of the corn oil modifies the flavor, though it undoubtedly improves the keeping qualities. In general, corn meal contains a little more fat and starch and a little less protein than wheat flour, but after all it resembles this staple foodstuff quite closely in chemical composition.

The changes brought about in corn by the heat of cooking are much the same as those observed in other cereal grains. Thus, the cell walls made up of indigestible crude fiber are softened and broken down and so the starch inside may be more readily reached by the digestive juices. Heat, with or without the presence of water, changes some of the insoluble starch into forms which are easily dissolved, a condition favorable for digestion. Cooking has further advantages in that it improves the flavor of corn and thoroughly sterilizes it, a matter which may be very important under some conditions.

Corn protein does not contain the elastic, tenacious gluten which is characteristic of wheat protein and so corn meal does not give a light porous loaf with yeast. For this reason corn meal alone is seldom used for raised bread, but is usually baked in thin cakes which are granular rather than porous, although such leavening material as eggs, sour milk with soda, etc., may be used in making the batter. When corn meal is mixed with wheat flour or rye flour the dough may be raised with yeast. Such bread, of which "rye and Indian" bread is a typical example, is most palatable when slowly cooked in rather large loaves. Corn meal is often used for making mush or porridge. Under the name "hasty pudding," this dish used to be a favorite in New England and is still frequently served as a supper dish.

Samp and hominy, which are much less finely ground than corn meal, are cooked like other grits and are commonly used as a breakfast cereal or as a vegetable to accompany meat. Hominy is now frequently made without the skin and germ. Like other similar cereal goods hominy and samp require long-continued and thorough cooking, especially when coarse.

Hulled corn is an old-fashioned dish in which the kernels, instead of being ground or degerminated, are steeped in lye until the hulls are loosened, soaked in clear water until free from alkali, and then boiled until soft and tender.

There are various proprietary breakfast foods made from corn. In most of these the grain has been cooked until tender and then rolled or flaked and sometimes parched with or without the addition of malt or other flavoring material.

Small hard varieties of corn when shaken over a hot fire pop or burst to a white, light mass, owing to the sudden expansion to steam of moisture in the cells making up the interior of the grain. Popped corn is sometimes used at table, but is usually eaten out of hand. The total amount consumed is fairly large. Varieties of corn which will not pop are sometimes parched and eaten and are also used as a coffee substitute.

Cornstarch has long been an important foodstuff commonly used for making puddings and desserts and for invalid cookery. Glucose made from cornstarch is a very common commercial product. The use of corn oil as a culinary fat is comparatively recent but seems promising.

Corn meal and other corn products are used in making an endless variety of batter breads, cakes, and other dishes for which recipes may be found in books devoted to cookery.

Unripe or green corn is frequently used as a vegetable, particularly in America. Like all green vegetables it is succulent and contains a small amount of nutritive material in proportion to its bulk, being esteemed for its pleasing flavor and the variety which it gives to the diet rather than for its direct food value. Corn canned alone or mixed with beans or tomatoes is a common commercial product, reasonable in price, and a useful addition to the list of vegetables, particularly in the winter diet.

Careful experiments made to test the digestibility of corn indicate that the carbohydrates are almost completely utilized by the body no matter how the grain is cooked. The method of preparation, however, apparently makes considerable difference in the digestibility of the protein. Thin, porous corn bread, such as johnnycake, and even the thick loaves of Boston brown bread, made of equal parts of corn, rye, and wheat, furnish as large a proportion of digestible protein as white wheat bread raised with yeast. On the other hand, the protein of hoecake (corn meal mixed with water and baked in thin sheets) has been found to be slightly less digestible than that of wheat bread, while the protein of hasty pudding and boiled hominy is only about 73 per cent digestible as compared with 83 to 86 per cent in the above-mentioned types of corn bread.

The corn breakfast foods and other corn products have much the same digestibility as corn meal when cooked in similar ways. The

variations which have been noted with the different corn breads and other corn dishes are of the same character as those observed with similar foods made from wheat flour of different sorts.

Corn, though a wholesome and very useful foodstuff which may be cooked in many ways, is not likely to replace wheat as a leading breadstuff where the latter can be obtained, as wheat bread is commonly considered to be more appetizing for everyday use and has an advantage in that it keeps for a longer time in good condition after baking. Corn breads, however, give a pleasant variety to the diet, and being more easily and quickly made than wheat bread are especially useful when hot bread is wanted and time is limited. Corn breads and corn cakes are so easily made that they are favorites in camps and wherever cooking appliances are few and simple.

Where conditions are especially favorable to corn cultivation, as in the mountain districts of the southeastern United States, some parts of Italy, and the Balkan regions of Europe, corn is often the staple cereal food and not infrequently the principal article of diet for the poor. In times of distress people have lived on this grain alone for considerable periods, but, like other grains, it contains too little protein in proportion to its fat and carbohydrates to supply the body with nutritive material in the proper proportion, and it should be combined with materials rich in protein, such as lean meat, milk, cheese, dry beans, etc. When thus combined it is a healthy, nutritious, and inexpensive food and has been proved by common experience to be wholesome, palatable, and a welcome addition to the diet.

Considering all of its uses, corn is one of the most important cereal foods from the standpoint of palatability, nutritive value, and digestibility. It may be prepared for the table in a great variety of ways, and in some form or other is deservedly used in the majority of American homes.

